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THE
AMERICAN
MATHEMATICAL MONTHLY.

Entered at the Post-office at Springfield, Missouri, as second-class matter.

VOL. XII. JUNE-JULY, 1905. NOS. 6-7.

THE BALLISTIC PROBLEM.

By S. A. COREY.

The problem of the motion of a projectile through a resisting medium, such as air, is discussed at some length by Gilman in the April number of the *Annals of Mathematics*. Of the three methods there given the most accurate is exceedingly laborious. The following method, based on Stirling's formula, is very accurate, simple, and involves but little labor.

It is known that Stirling's formula may be used to develop the following formula:*

$$f(a+x)=f(a)+\frac{x}{m}\left[\frac{f'(a+x)+f'(a)}{2}+f'\left(a+\frac{x}{m}\right)+f'\left(a+\frac{2x}{m}\right)\right.$$

$$\left.+f'\left(a+\frac{3x}{m}\right)+\dots\dots+f'\left(a+\frac{m-1}{m}x\right)\right]-\frac{B_1\,x^2}{m^2.2!}\left[f''(a+x)-f''(a)\right]$$

$$+\frac{B_2\,x^4}{m^4.4!}\left[f^{\text{iv}}(a+x)-f^{\text{iv}}(a)\right]-\dots\dots$$

$$+(-1)^n\frac{B_n x^{2n}}{m^m.(2n)!}\left[f^{(2n)}(a+x)-f^{(2n)}(a)\right]+\dots\dots(A),$$

B_1, B_2, B_3, etc., being Bernoulli's numbers, $\frac{1}{6}$, $\frac{1}{30}$, $\frac{1}{42}$, etc.

Using the first two terms only and taking $m=3$, (A) becomes

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*See *Annals of Mathematics*, Vol. 5, No. 4, July, 1904.

$$f(a+x)=f(a)+\frac{x}{3}\left[\frac{f'(a+x)+f''(a)}{2}+f'\left(\frac{2x}{3}\right)+f'\left(\frac{x}{3}\right)\right]$$

$$-\frac{x^2}{108}\Big[f''(a+x)-f''(a)\Big] \text{ .... } (1),$$

or, applying (1) to the evaluation of one of the integrals considered by Gilman, viz.,

$$cdx=\frac{dp}{p\sqrt{(1+p^2)}+\log[p+\sqrt{(1+p^2)}]-C}=F'(p)dp \text{ .... } (2),$$

where $C=3.455425$, $c=.0000339822$, initial angle of elevation $\theta=30^\circ$, $p=\tan\theta=.57735$, and x=distance from muzzle of gun to the point of highest elevation in the flight of the projectile, we have

$$x=\frac{p}{3c}\left[\frac{F'(0)+F'(p)}{2}+F'\left(\frac{p}{3}\right)+F'\left(\frac{2p}{3}\right)-\frac{p^2}{108^\circ}\Big[F''(p)-F''(0)\Big]\right. \text{ .... } (3).$$

Differentiating $F'(p)$ with reference to p, and reducing, we get

$$F''(p)=-\frac{2[F'(p)]^2}{\cos\theta}$$

To permit the use of logarithms to advantage $F'(p)$ may be written

$$1\div\left[\frac{\tan\theta}{\cos\theta}+\log 2+2\log\sin(45^\circ+\tfrac{1}{2}\theta)-\log\cos\theta-C\right] \text{ .... } (4).$$

Computing $F'(0)$, $F'\left(\frac{p}{3}\right)$, $F'\left(\frac{2p}{3}\right)$, and $F'(p)$ by (4),

$$\begin{aligned}
\tfrac{1}{2}F'(0) &= .14470\\
F'\left(\frac{p}{3}\right) &= .32593\\
F'\left(\frac{2p}{3}\right) &= .37495\\
\tfrac{1}{2}F'(p) &= .22327\\
\hline
\text{Sum} &= 1.06885\\
\text{Sum}\div 3 &= .35628
\end{aligned}$$

The first term of (3) then becomes, $\dfrac{.57735\times .35628}{.0000339822}=6053.1$ feet.

The second term of (3) likewise becomes,

$$\frac{.57735^4\left(\frac{.44654^2}{.86603}-.28940^2\ \right)}{54\times.0000339822}=-26.6 \text{ feet.}$$

Sum of the first and second terms of (3) gives, as the value of x. 6026.5 feet. This result is less than 1 foot in error.

For still greater accuracy either larger values of m may be taken or more than two terms of (A) may be employed.

It is perhaps needless to point out that the same method of evaluating the integrals for y and t may be quite conveniently employed.

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OUTLINE OF A COHERENT COURSE IN COLLEGE ALGEBRA.

By DR. A. C. LUNN.

In teaching what may be considered the standard topics in a course on College Algebra it is often difficult to avoid leaving with the students the impression that they have labored over a set of isolated subjects, hard to master because of lack of interrelations. The following outline sketches the result of an attempt to organize many of these subjects into a course, to be developed so that a certain natural unity should be more or less obvious.

§1. The Fundamental Problems.

The main subject is the study of rational functions of a single real variable, in three aspects, the Formula, the Graph, and the Table, denoted in the following by their initial letters. The motto is that every notion, operation, and problem connected with the theory is to be interpreted so far as possible in all three aspects.

By "formula" is understood an algebraic statement of the form $y=f(x)$, giving directions for finding the value of the dependent variable y in terms of the argument x by a certain set of operations, $f(x)$ denoting for the present purpose "an expression in terms of x". The functions or expressions considered here are then either polynomials of the form $A_0x^n+A_1x^{n-1}$ .... $A_{n-1}x+A_n$, or quotients of such, although opportunity is presented for easy passage to certain irrational forms if desired, and certain of the theorems deduced apply to wide classes of functions.

By "graph" is understood a plot of the curve whose equation is $y=f(x)$ in Cartesian coördinates, where the two units of measure are chosen independently according to dictates of convenience for the two axes (not necessarily rectangular), since for present purposes lengths are compared only when parallel.

By a "table" is meant an array of numerical values of y corresponding to assigned values of x, and where not otherwise specified it is understood that the